High-Frequency Scattering from the Sea Surface and Multiple Scattering from Bubbles

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Award Number: N00014-96-1-0325

Thrust Category: High-Frequency Acoustics

LONG-TERM GOALS

To develop a comprehensive understanding of (**1**) high-frequency scattering from the air-sea interface and its relation to the directional wave spectrum, including scattering from bubbles near this interface, and (**2**) of high-frequency acoustic propagation and scattering in bubbly media characteristic of the surf zone, and the near-surface acoustic environment. The ultimate goal is to obtain realistic, physics-based, predictive models for scattering and propagation phenomena.

OBJECTIVES

To conduct field studies in bistatic sea surface scattering and laboratory studies in multiple scattering from well-characterized bubble fields, and to interpret results from these experiments with physical models.
Examples of laboratory and field data taken by the PI are described in Refs. [1-3].

APPROACH

A multiple scattering series [1] is used to interpret laboratory measurements of multiple scattering from bubbles. Laboratory studies of scattering from bubbles in the vicinity of an air-water boundary are interpreted, in part, by a ray-synthesis approach (consisting of four paths), e.g., as described by Sarkar and Prosperetii [4]. The small slope approximation [2,5] is used to interpret field measurements of bistatic scattering.

WORK COMPLETED

This year field data from the 1992 FLIP experiment [3] was revisited in order to extract time spreading information from, and determine the influence of near-surface bubbles on, measurements of bistatic forward scattering. Also, laboratory experiments[1] multiple scattering from bubbles were completed, and of bistatic and monostatic backscattering [see Fig. 2] from a single bubble precisely positioned a distance d from both a calm and roughened air-water surface.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**
4. TITLE AND SUBTITLE **High-Frequency Scattering from the Sea Surface and Multiple Scattering from Bubbles**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Applied Physics Laboratory,College of Ocean and Fisheries Sciences,,University of Washington,,Seattle,,WA,98105**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

RESULTS

Regarding our work in sea surface scattering, efforts this year focused on predicting the effects of changing environment and geometry on the characteristics scales of time and angle spreading, and the influence of bubbles on bistatic forward scattering. Results of this work are summarized in Ref. [6]. An example of subtleties in the influence of bubbles on bistatic forward scattering is shown in Fig. 1. The plot shows an ensemble average of 50 transmissions of 4-ms duration with a center frequency of 30 kHz, transmitted at 1-s intervals. A model representation is computed based on the sonar constants, the geometry (range = 995 m, source depth = 147 m, receiver depth = 28 m), and sea surface environmental conditions (wind speed = 8 m/s). In one case the model assumes a bubble-free environment, with the model result being too high by about 3 dB. In the other case the model includes the effect of bubbles, and better agreement with the data is achieved. The key parameter is the depth-integrated bubble extinction cross section per unit volume. Importantly, the effect of a near-surface bubble layer is largely confined to reducing the amplitude of the forward-scattered signal, rather than contributing to additional time or angle spreading.

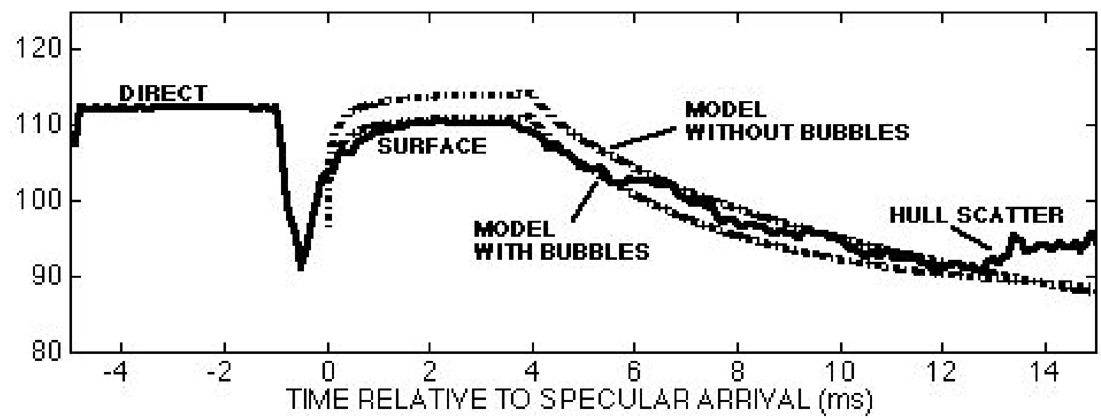

Figure 1. Ensemble average of 50 transmissions of 4-ms duration with a center frequency of 30 kHz, transmitted at 1-s intervals. (y-axis is received pressure level in decibels.) The measurements were made from the research platform FLIP. Model representation is computed based on the sonar constants, the geometry (range = 995 m, source depth = 147 m, receiver depth = 28 m), and sea surface environmental conditions (wind speed = 8 m/s). From Ref. [6].

Figure 2 shows some recent results from our laboratory measurements of scattering by a single bubble (frequency 120 kHz) precisely position a distance *d* below an air-water interface. The left-hand plot shows bistatic scattering (source and receiver slightly separated) as a function of *d/a* where *d* is distance between the air-water interface and *a* is bubble radius (equal to 420 microns). The right hand plot shows monostatic scattering (source and receiver co-located). For a bubble located in the free field, i.e., far from any boundaries, the results should look identical. However, the existence of four paths between source, bubble, and receiver, produces a significant difference between monostatic and bistatic scattering. The parameter governing this is the acoustic wavelength divided by the source/receiver separation. For the monostatic case, the target strength varies between extremely small values (indistinguishable from our noise floor), to 12 dB above the free field value for target strength, depending on *d/a*.

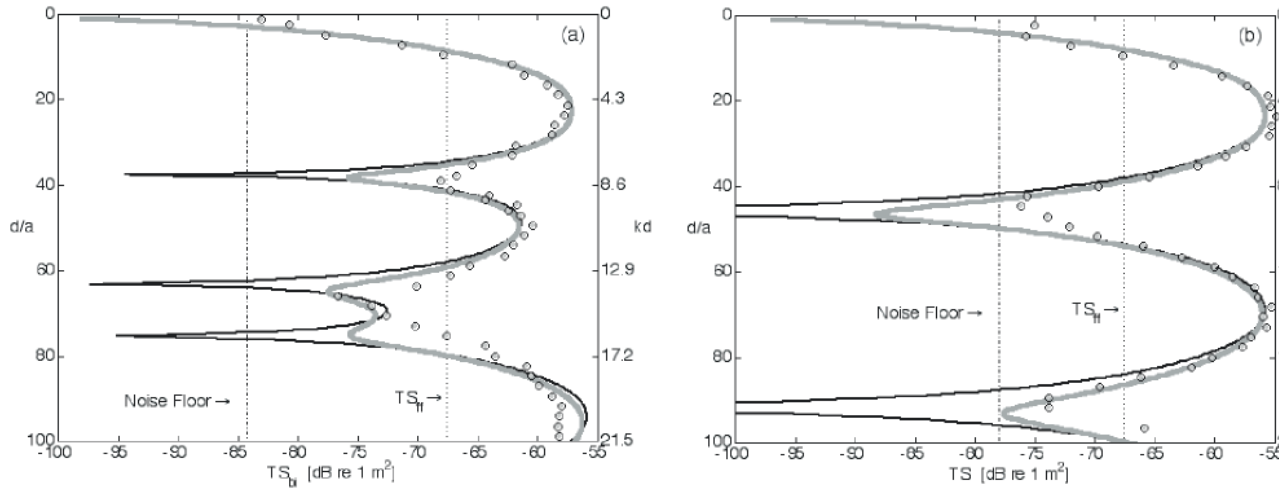

Figure 2. The left-hand plot shows bistatic scattering (source and receiver slightly separated) as a function of d/a where d is distance beneath the air-water interface and a is bubble radius. The right hand plot shows monostatic scattering (source and receiver co-located). Data are represented by open circles, narrowband model shown by the thin black line, model that includes the effects of the measurement bandwidth shown by the gray line.

IMPACT/APPLICATIONS

Bistatic scattering from the sea surface is a key feature of the acoustic environment that determines the performance of sonar systems that operate either in shallow water or in the vicinity of the sea surface. One application receiving increased attention is that of long-range synthetic aperture sonar (SAS) for which forward scattering from the sea surface becomes important. In this work we have established a relation between the bistatic cross section of the sea surface and the spatial and frequency coherence (or time spreading) in surface scattering. The performance bounds of long-range SAS are strongly linked to the coherence of the surface bounce path.

Our laboratory work on bubble scattering has broad implications in terms of how the level of reverberation originating from the vicinity of the sea surface is interpreted viz. near surface bubble density.

TRANSITIONS

This work relates directly to other ONR programs (both 6.1 and 6.2) that involve frequencies in the > 10 kHz range, and scattering from the surface and near-surface bubble layer, and contributes to a physics-based foundation for models used in Torpedo, MCM, and SAS system performance predictions.

RELATED PROJECTS

Programs that relate to, and complement this work include*: High Frequency Broadband Time/Frequency Spreading* (Lee Culver ,ARL/PSU), *Bubbles and Turbulence in the Ocean Surface Layer*, (D. Farmer, IOS), and *Fluctuations in High Frequency Acoustic Propagation* (W. Hodgkiss and W. Kuperman, MPL).

The PI is also involved in the *program Performance bounds on Long-Range SAS Associated with Sea Surface Scattering,* sponsored by ONR Code 321TS, for which results from this program are applied directly to the study of Synthetic Aperture Sonar (SAS) systems.

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PUBLICATIONS

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